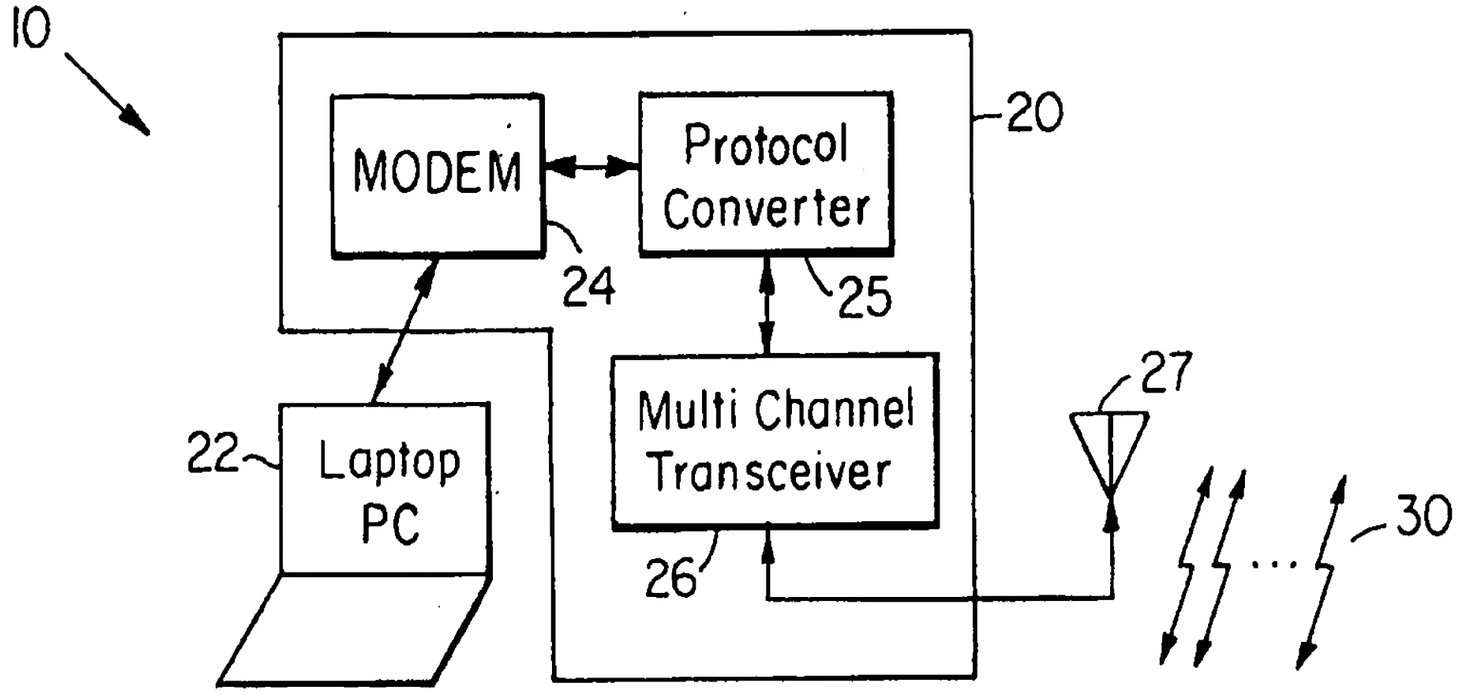
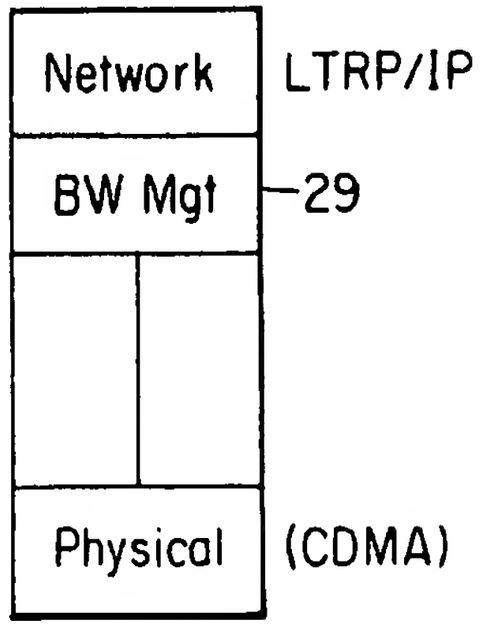

10
20
MODEM
Protocol Converter
24
25
Multi Channel Transceiver
27
22
Laptop PC
26
30


Network
LTRP/IP
BW Mgt
29
Physical
(CDMA)

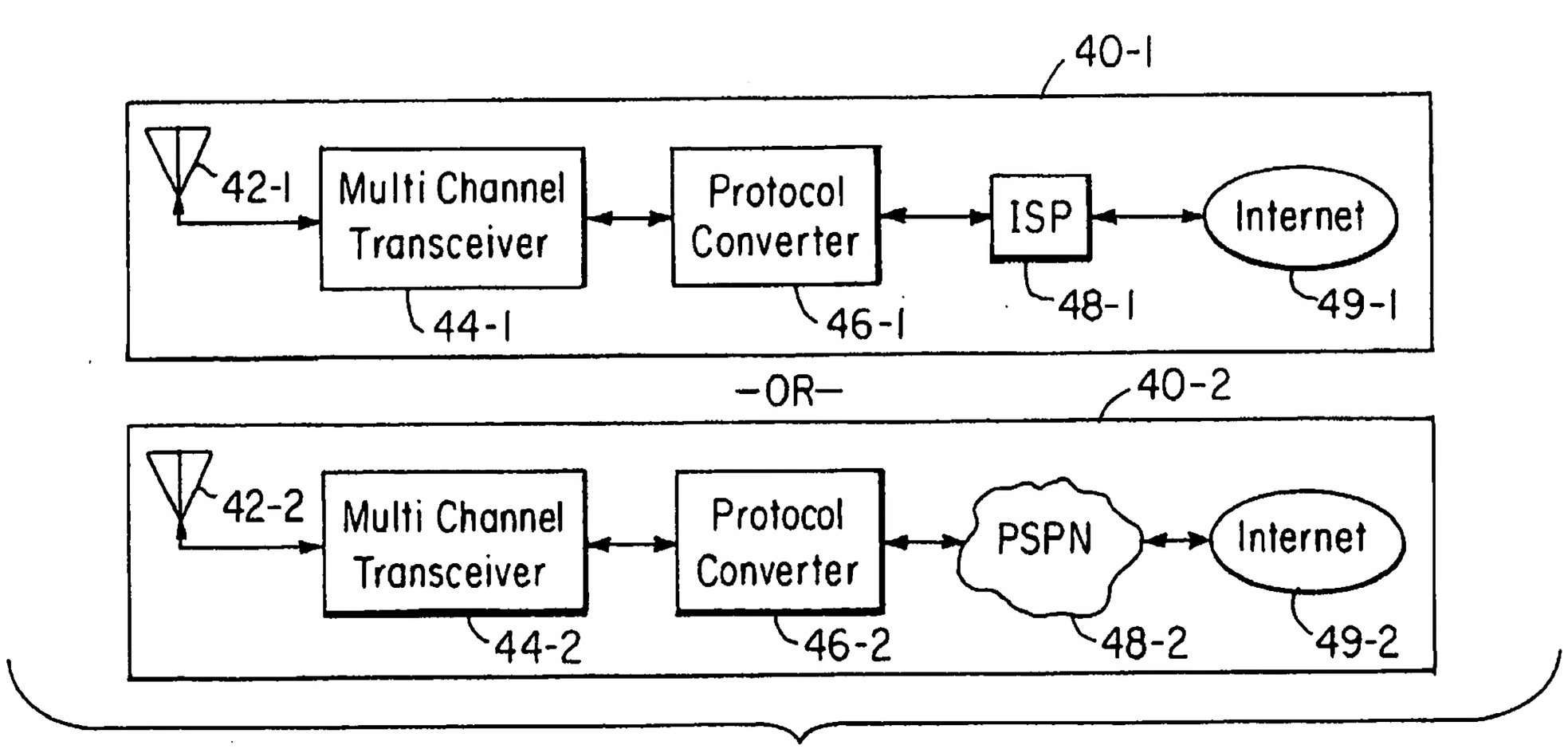

40-1
42-1
Multi Channel Transceiver
Protocol Converter
ISP
Internet
44-1
46-1
48-1
49-1
-OR-
40-2
42-2
Multi Channel Transceiver
Protocol Converter
PSPN
Internet
44-2
46-2
48-2
49-2

FIG. 1

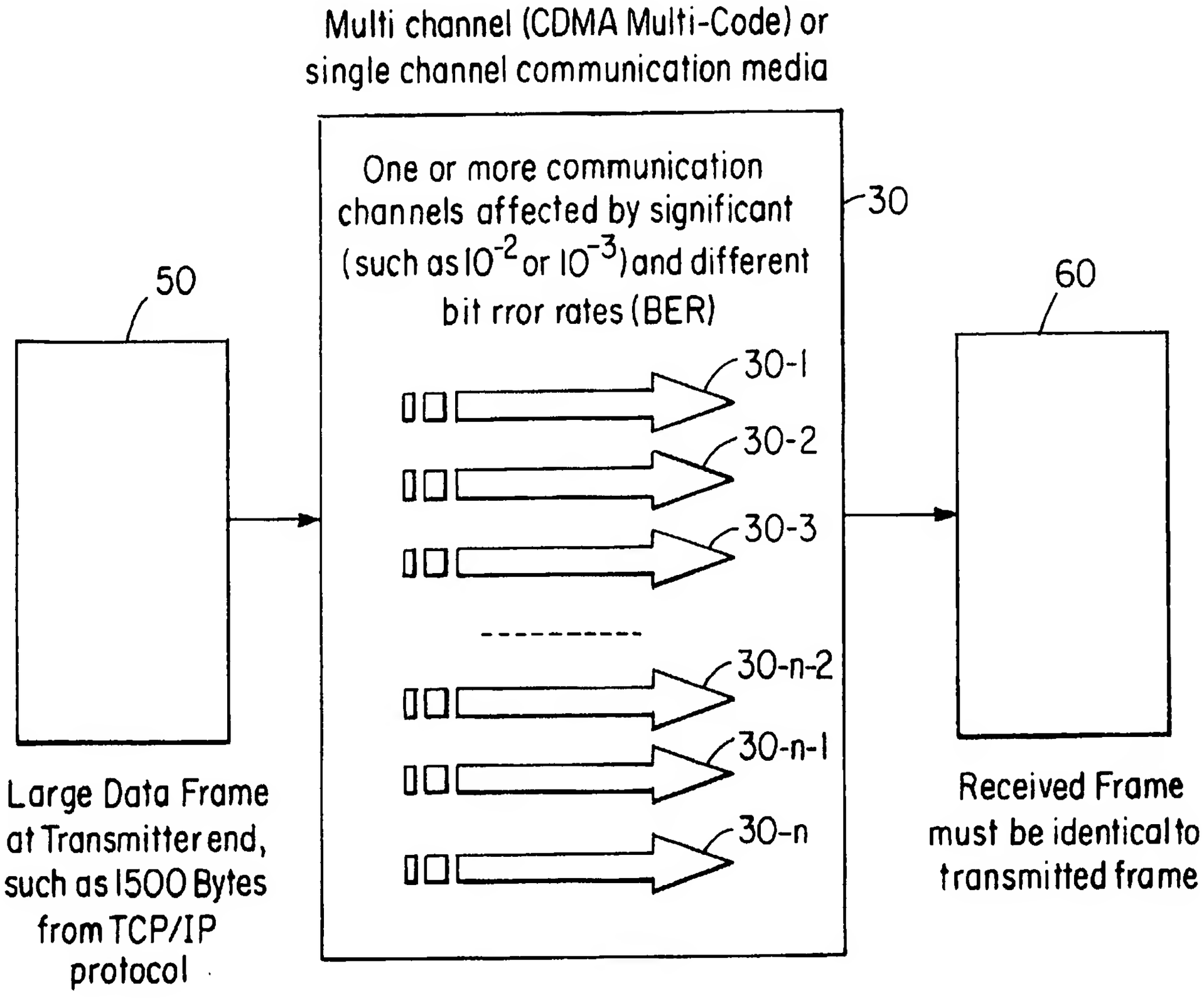

Multi channel (CDMA Multi-Code) or single channel communication media
One or more communication channels affected by significant (such as 10^{-2} or 10^{-3}) and different bit rror rates (BER)
30
50
60
30-1
30-2
30-3
30-n-2
30-n-1
30-n
Large Data Frame at Transmitter end, such as 1500 Bytes from TCP/IP protocol
Received Frame must be identical to transmitted frame

FIG. 2

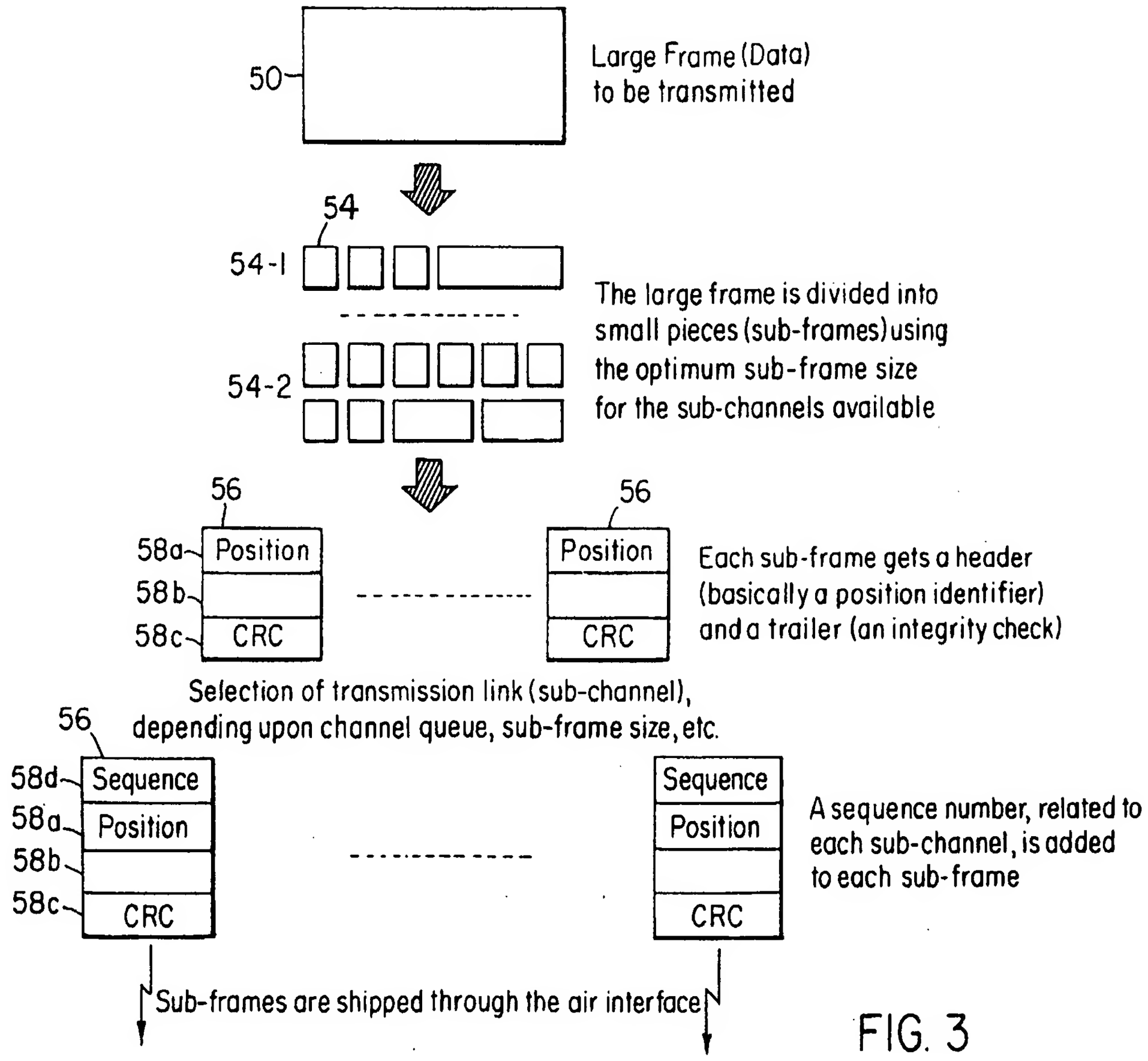

50
Large Frame (Data)
to be transmitted
54
54-1
54-2
The large frame is divided into
small pieces (sub-frames) using
the optimum sub-frame size
for the sub-channels available
56
56
58a
Position
58b
58c
CRC
Position
CRC
Each sub-frame gets a header
(basically a position identifier)
and a trailer (an integrity check)
Selection of transmission link (sub-channel),
depending upon channel queue, sub-frame size, etc.
56
58d
Sequence
58a
Position
58b
58c
CRC
Sequence
Position
CRC
A sequence number, related to
each sub-channel, is added
to each sub-frame
Sub-frames are shipped through the air interface

FIG. 3

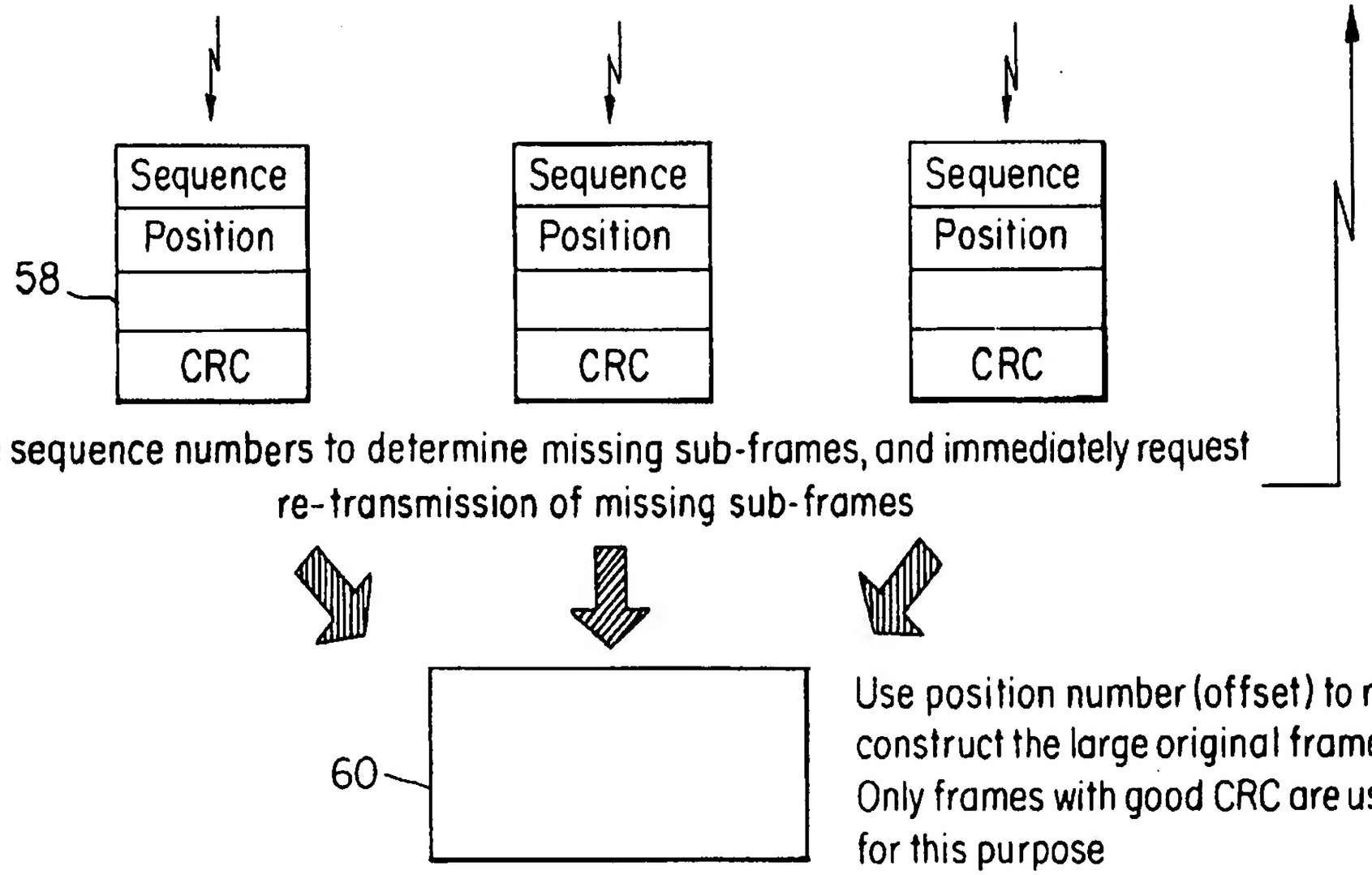

Sequence
Position
CRC
58
Sequence
Position
CRC
Sequence
Position
CRC
Use sequence numbers to determine missing sub-frames, and immediately request re-transmission of missing sub-frames
60
Use position number (offset) to re-construct the large original frame. Only frames with good CRC are used for this purpose
Check if any piece of the large frame is still missing when the end-of-frame command is received. If any is still missing, request retransmission of the sub-frame at position, specifying length.
Both Sender and Receiver know the ratio of sub-frames received with errors and received without errors. They also know the average sub-frame length for each sub-channel. Then they can update the optimum sub-frame size for each sub-channel

FIG. 4

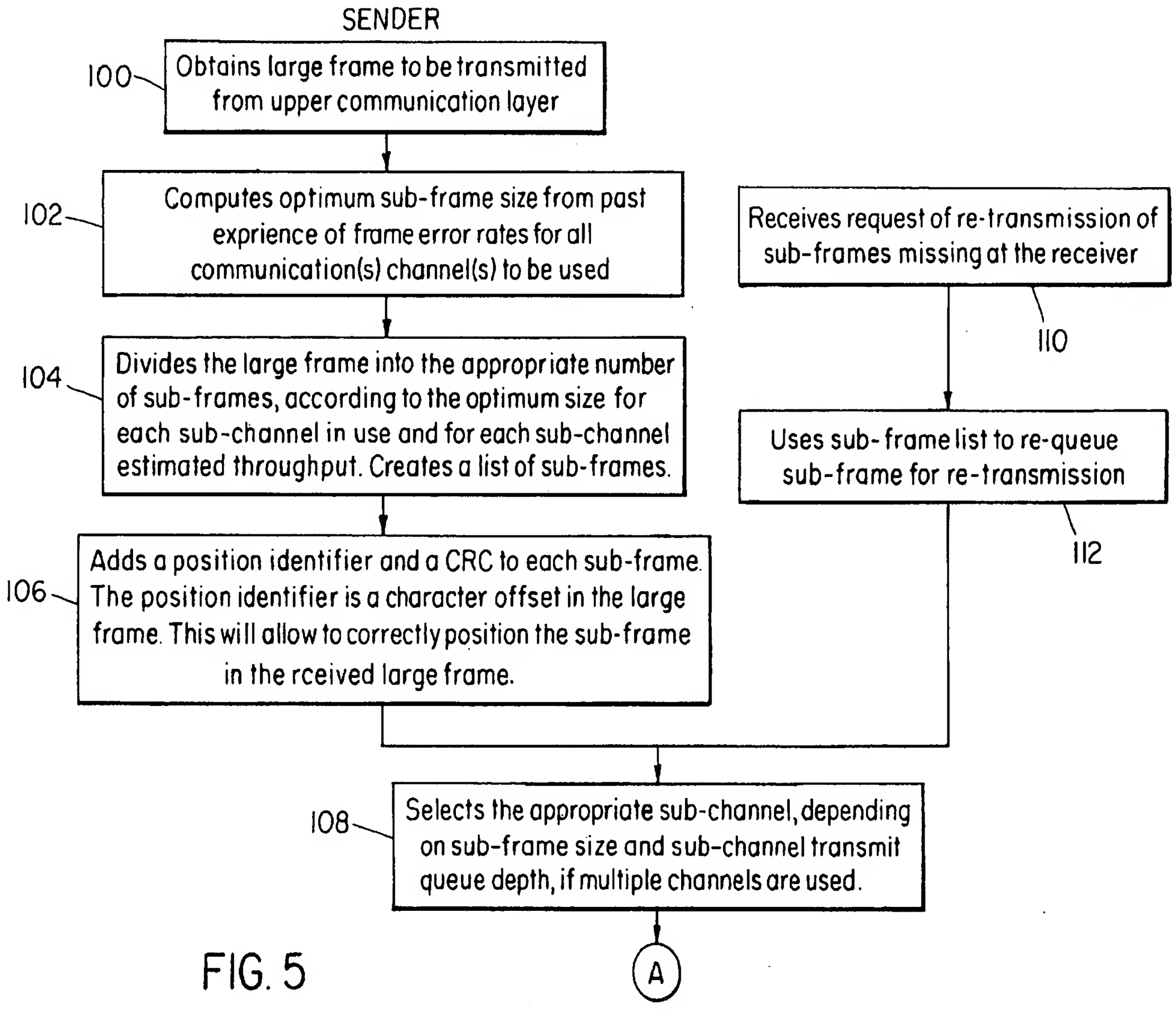

SENDER
100
Obtains large frame to be transmitted from upper communication layer
102
Computes optimum sub-frame size from past exprience of frame error rates for all communication(s) channel(s) to be used
104
Divides the large frame into the appropriate number of sub-frames, according to the optimum size for each sub-channel in use and for each sub-channel estimated throughput. Creates a list of sub-frames.
106
Adds a position identifier and a CRC to each sub-frame. The position identifier is a character offset in the large frame. This will allow to correctly position the sub-frame in the rceived large frame.
108
Selects the appropriate sub-channel, depending on sub-frame size and sub-channel transmit queue depth, if multiple channels are used.
A
Receives request of re-transmission of sub-frames missing at the receiver
110
Uses sub-frame list to re-queue sub-frame for re-transmission
112

FIG. 5

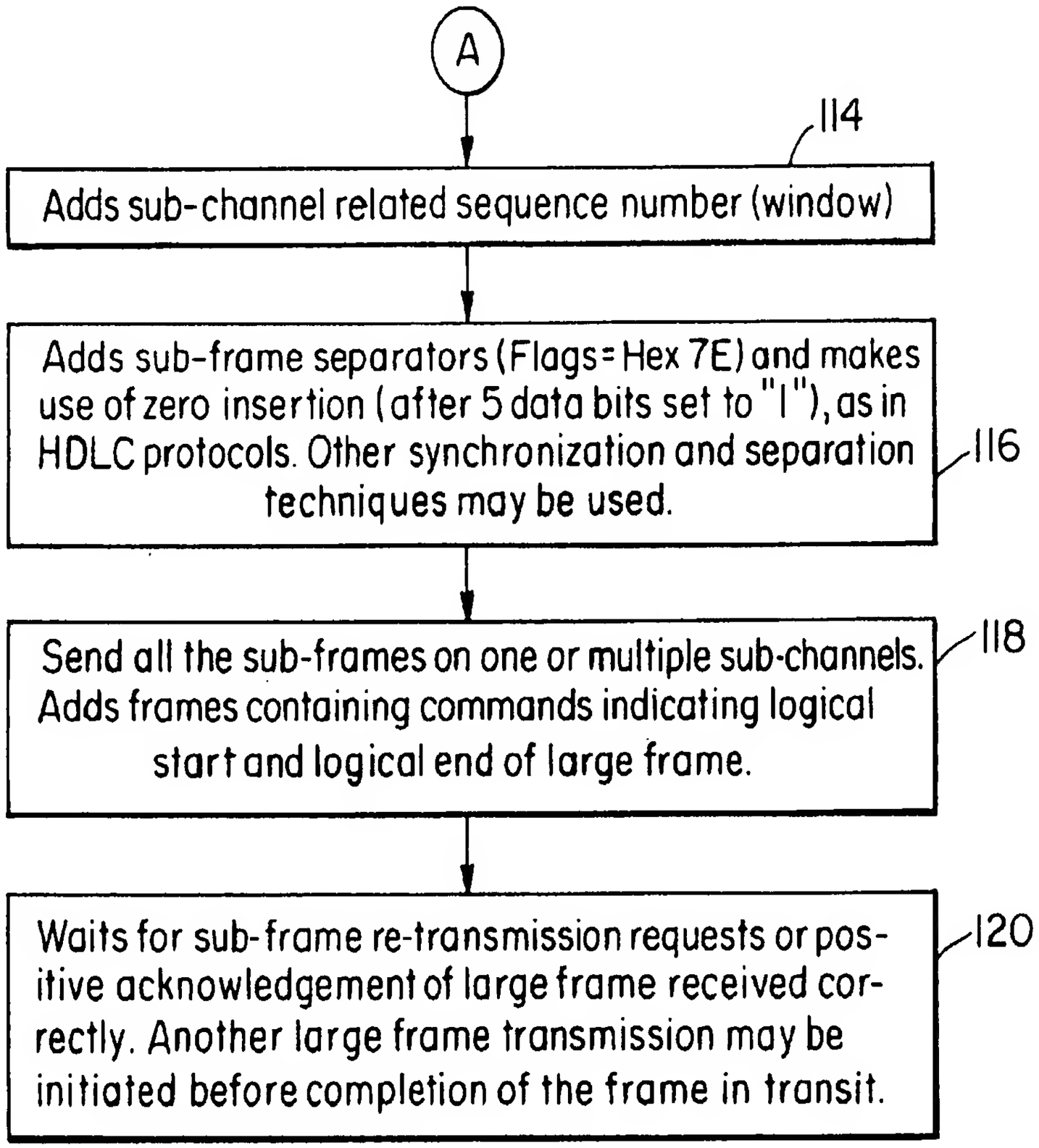
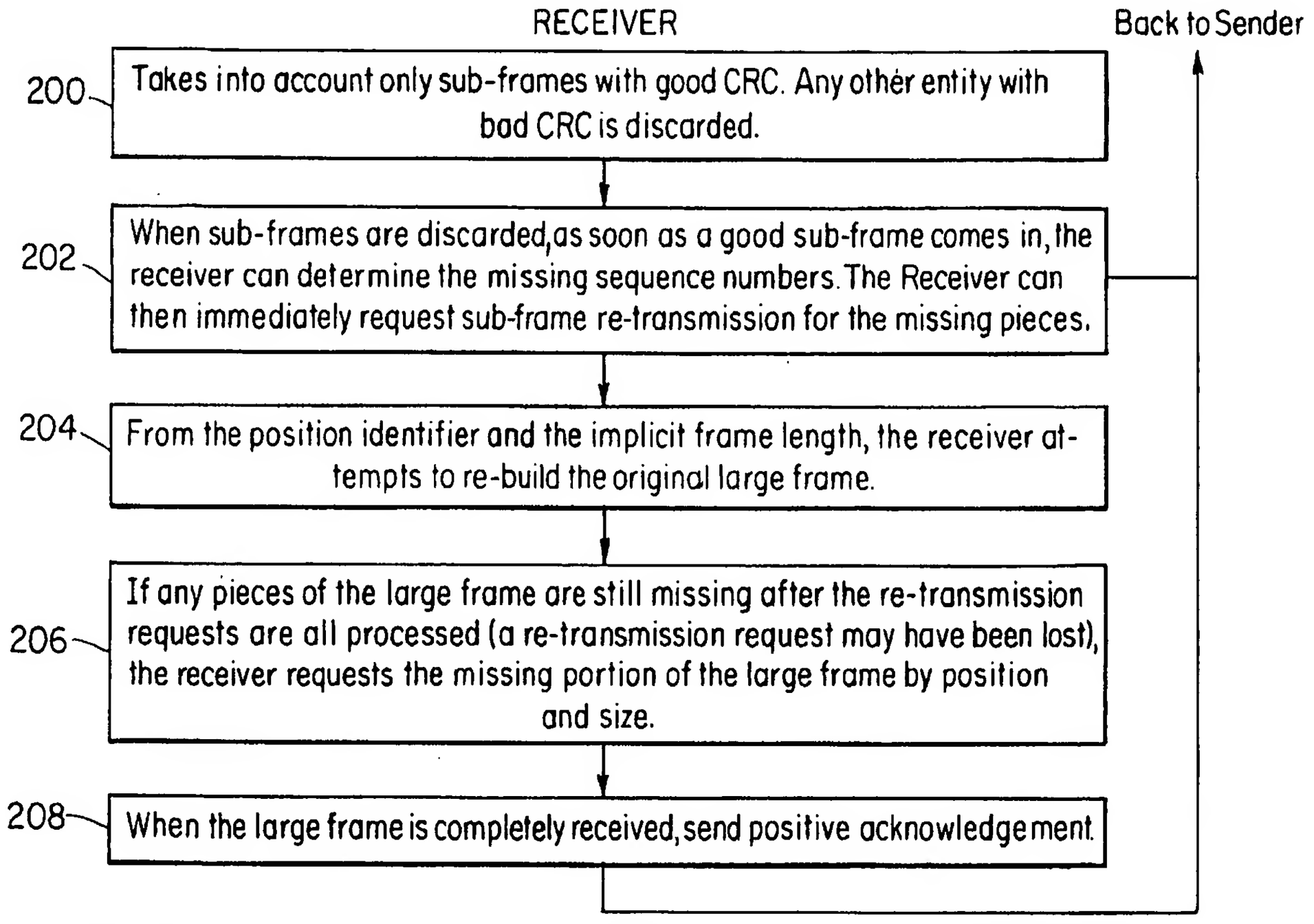

A
114
Adds sub-channel related sequence number (window)
Adds sub-frame separators (Flags = Hex 7E) and makes use of zero insertion (after 5 data bits set to "1"), as in HDLC protocols. Other synchronization and separation techniques may be used.
116
Send all the sub-frames on one or multiple sub-channels. Adds frames containing commands indicating logical start and logical end of large frame.
118
Waits for sub-frame re-transmission requests or positive acknowledgement of large frame received correctly. Another large frame transmission may be initiated before completion of the frame in transit.
120

FIG. 6



Note that the transission sub-layer described here does not have to ensure perfect integrity. The large frame includes it's own CRC and other higher layer protocol elements to ensure data integrity. An error in the sub-layer described here is equivalent to bit error perceived at the higher layer. The sub-layer only strives to improve BER, not generate absolute data integrity.

FIG. 7

Sub-Frame Structure

Field	Proposed Number of Bits
Data/Command Indicator	1
Large Frame sequence number (Window of 2)	1
Character offset of sub-frame into large frame	11
Sub-Channel sequence number (Window of 7)	3
Data	0 to 2048
CRC	12
Shared Flag (Hex 7E)	8

This sub-frame structure is suitable for sub-channel utilization (Multi-link) use on media with high Bit Error Rates (BER)

FIG. 8

One bit error every n bits on "raw" sub-channels		# of Sub-Channels with same characteristics	Effective sub-channel transfer rate	Cumulative Sub-Channel transfer rates
50	High	2	2000	4000
500	Med	5	6000	30000
5000	Low	13	8000	104000
TOTAL		20		138000

FIG. 9

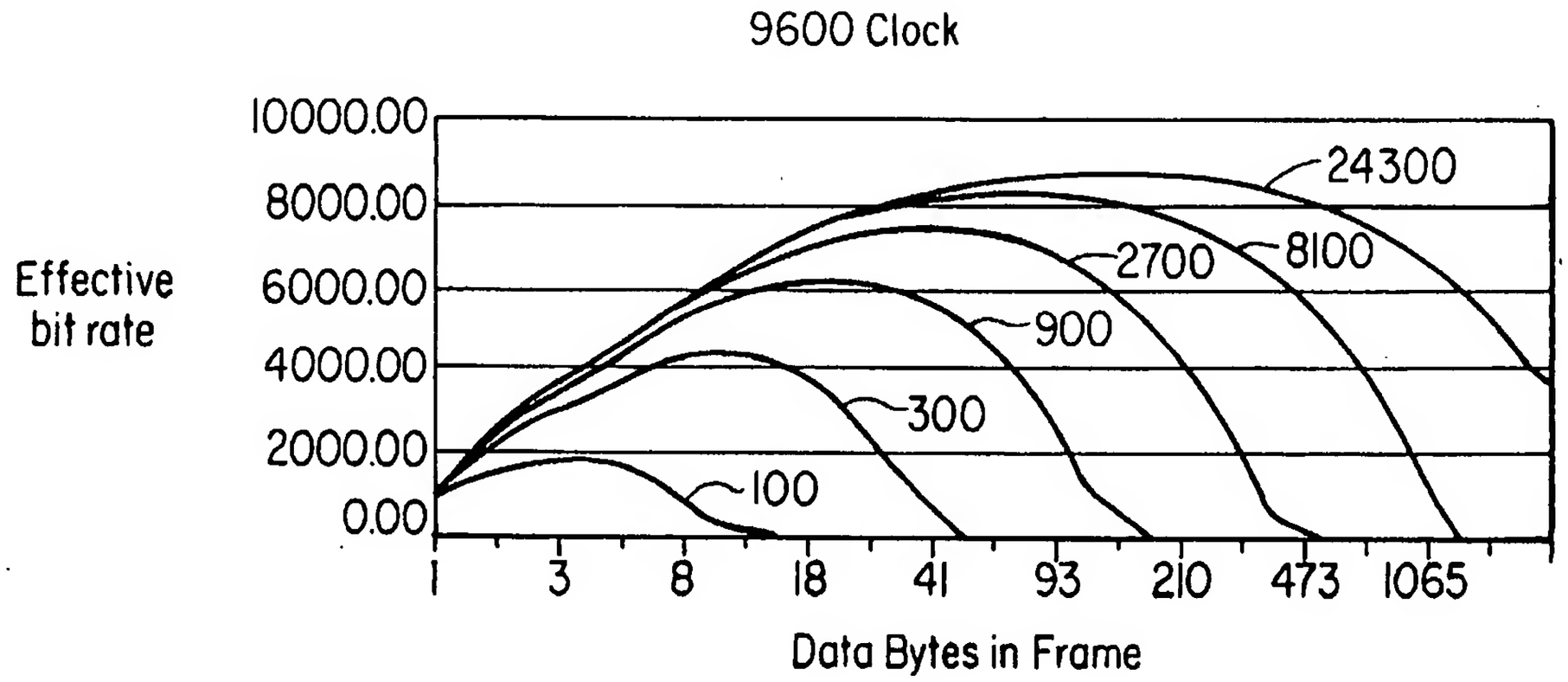


FIG. 10